Advanced Space Transportation Program

Space Transportation

Application of Overset Technology on SIMPLEX Turbopump Design

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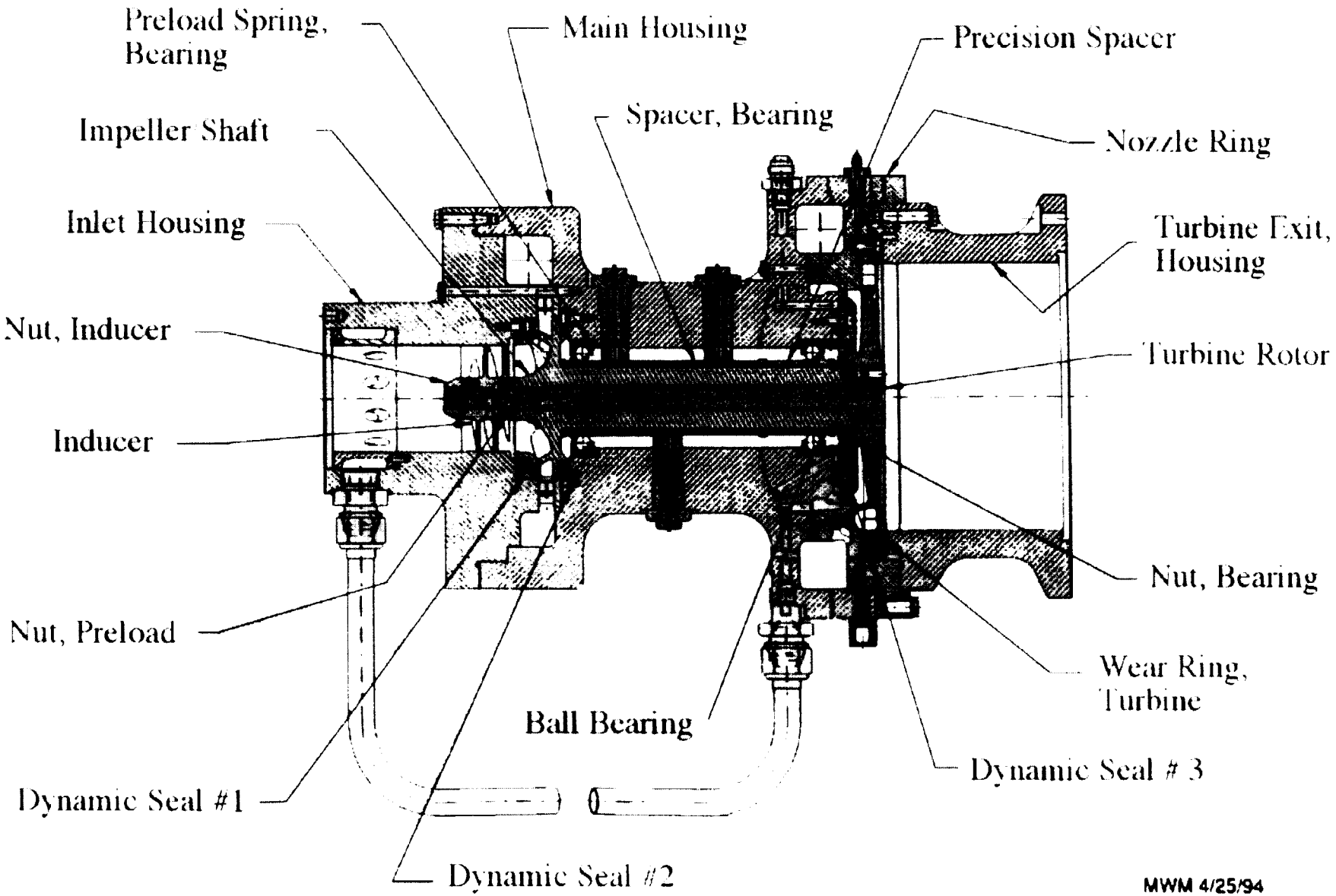
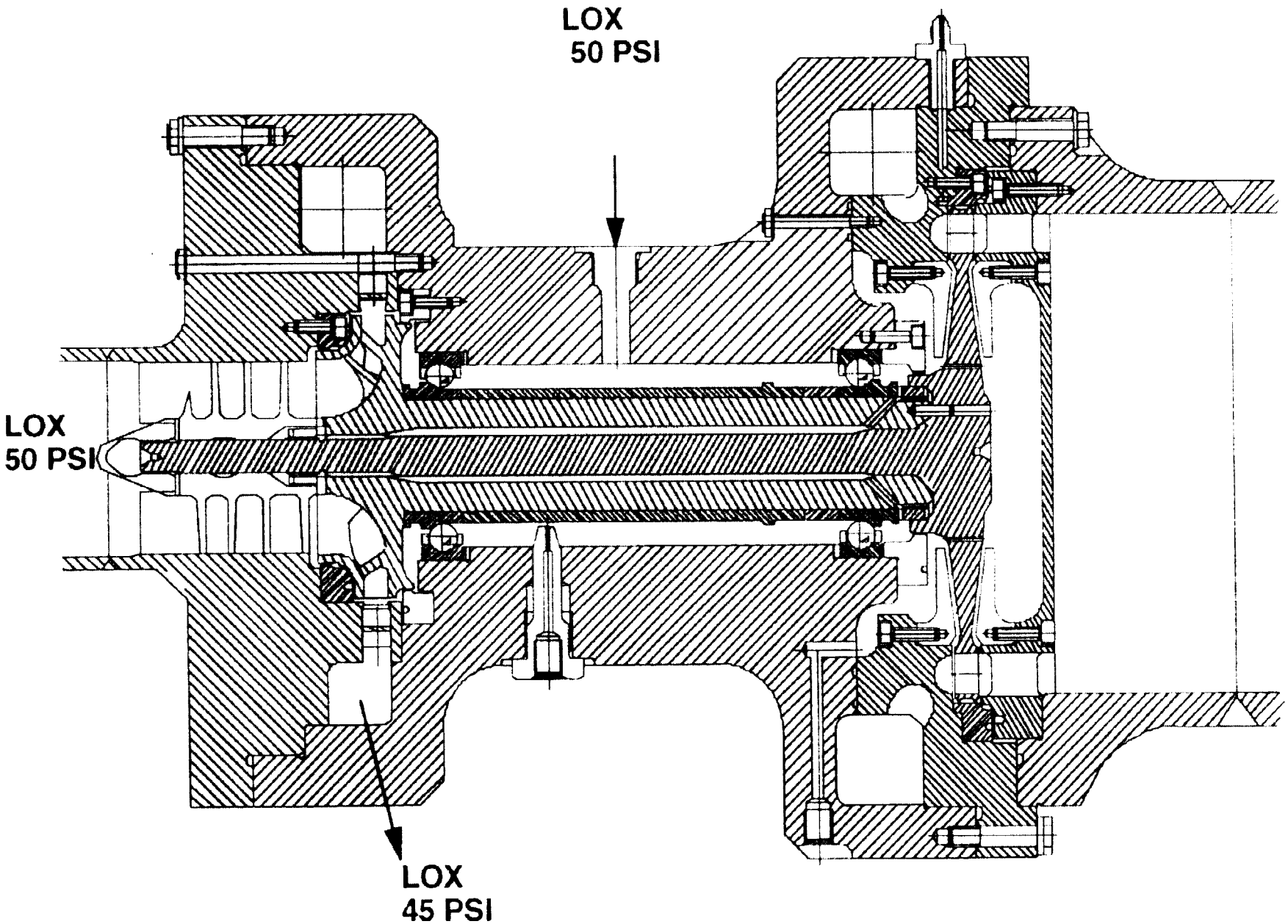
Objective

- To support the Functional Design Group
- To predict more accurate data using a Chimera technique
- To compare with previous (uncoupled) calculations
- To provide an unsteady environment

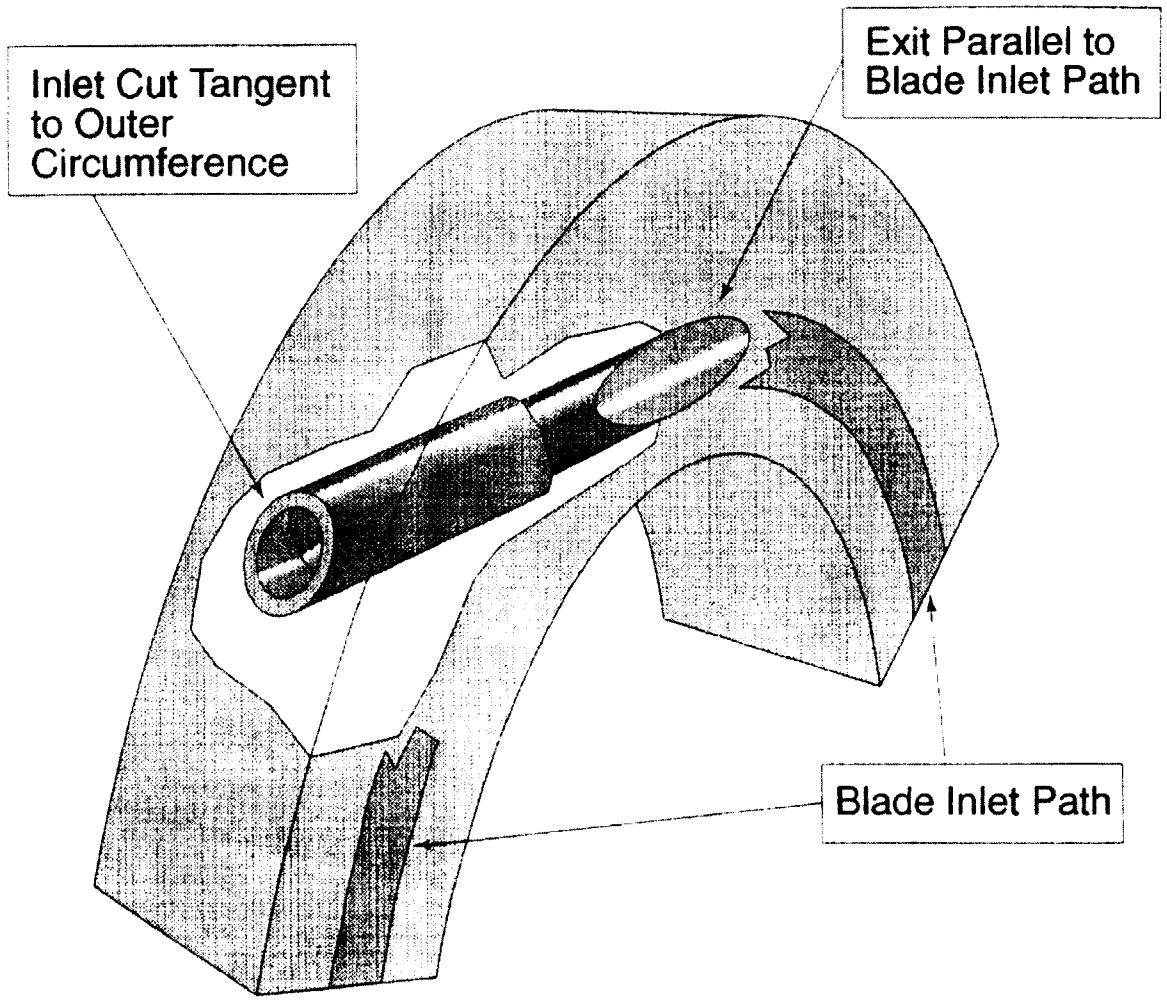
Simplex Turbopump



MWM 4/25/94

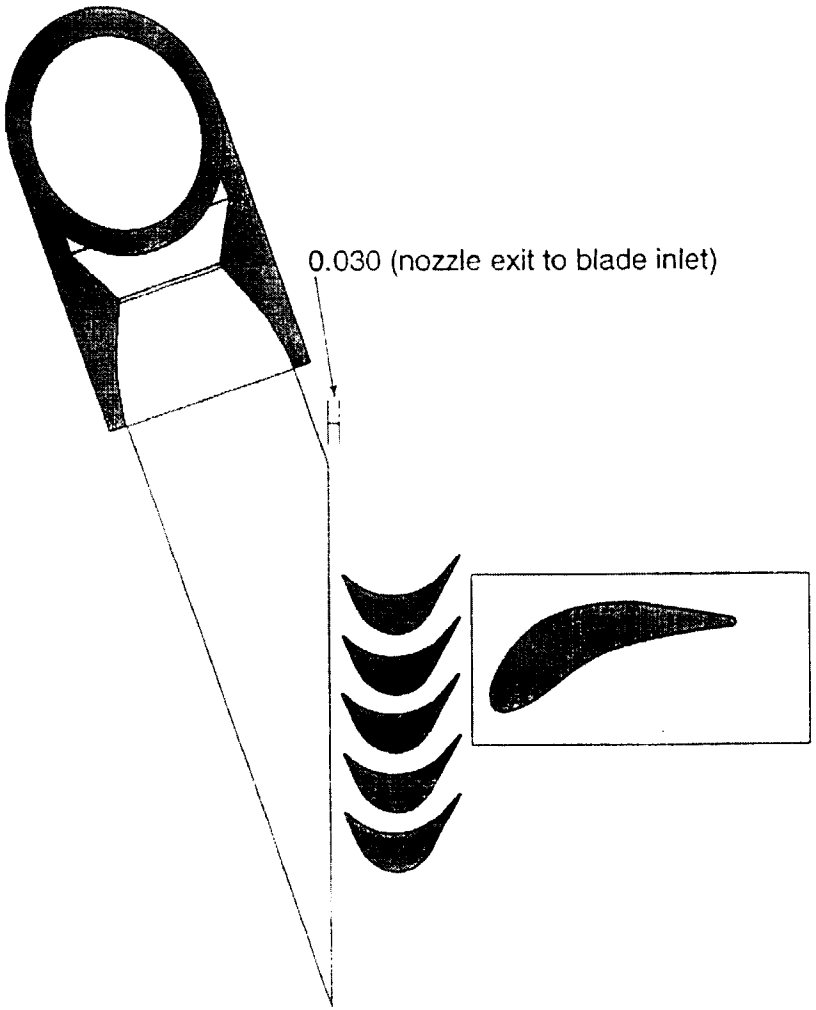

LOX
50 PSI
LOX
50 PSI
LOX
45 PSI

Cutaway of Simplex Nozzle Ring Assy



Simplex Turbine Gas Flow Path

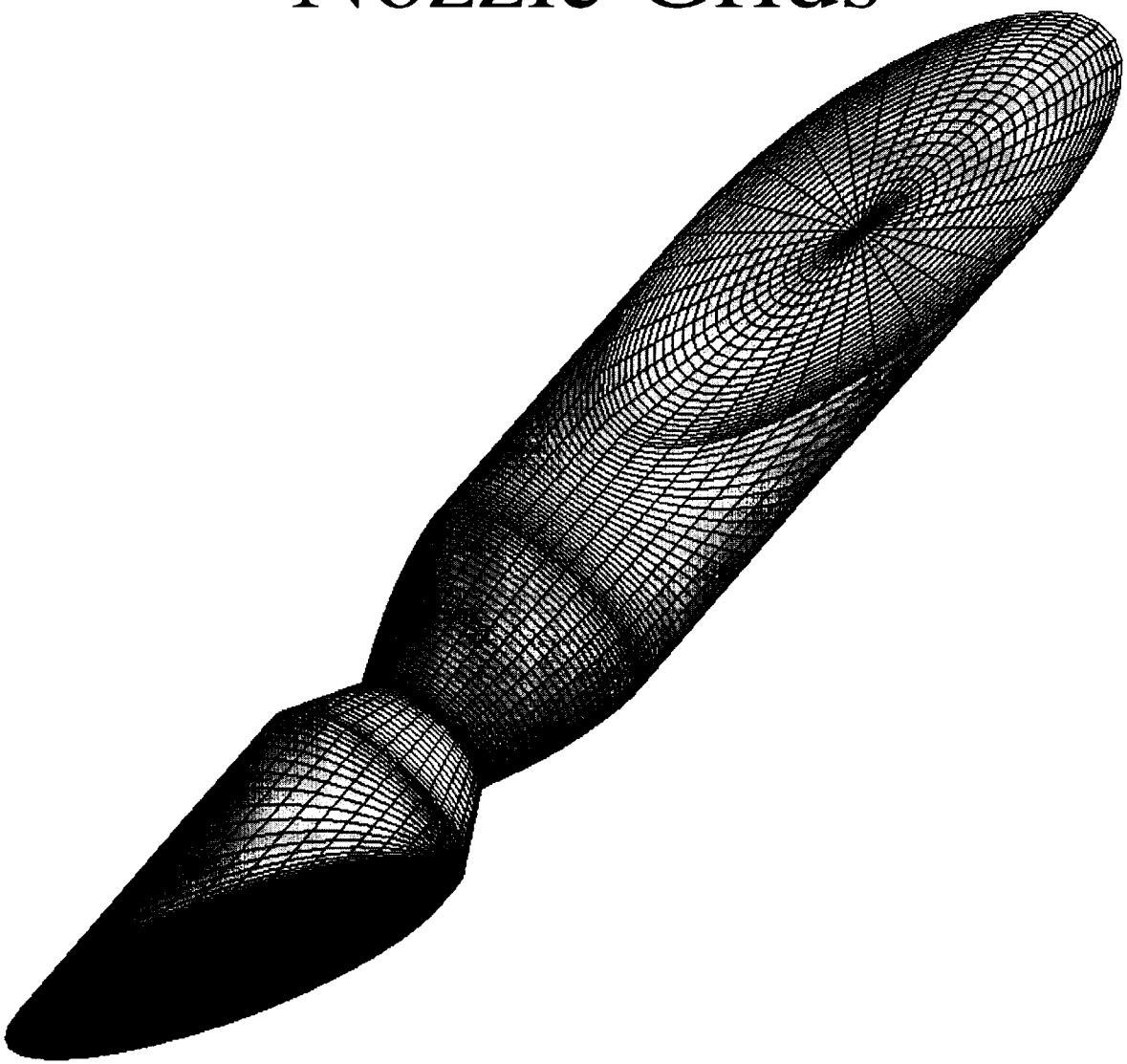
to scale
dimensions in inches



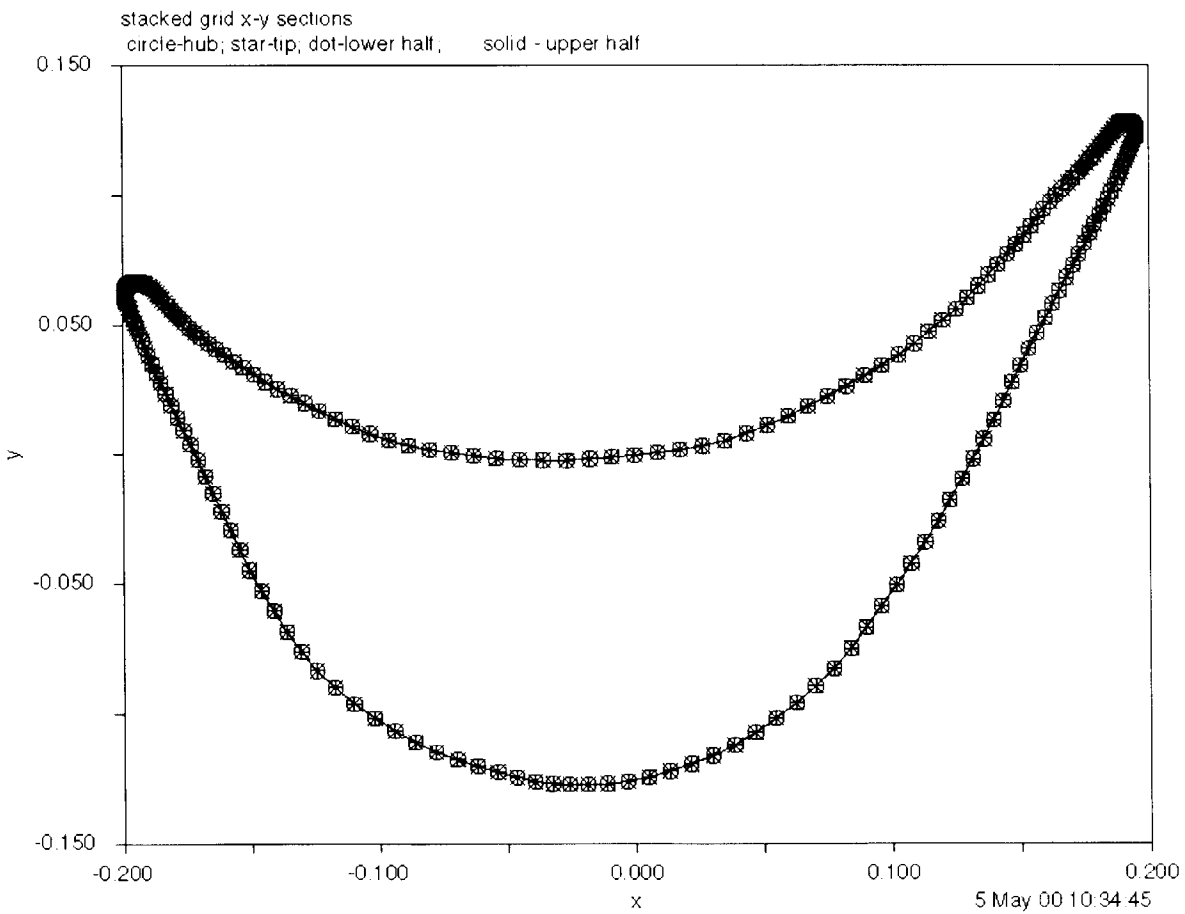
Grid Generation

- Overset grids using Corgrid
- Nozzle grids (O type)
- Blade grids (O and H type)
- Interface (duct) grid (H and O type), O grid is required by Corgrid but not used in flow solver
- Turbine includes 12 nozzles and 95 blades.
- Model includes 1 nozzle and 8 blades; 95/96 factor is compensated in Corgrid
- Total of 1,787,550 grid points , reduced to 1,060,798 to fit in SGI Challenge

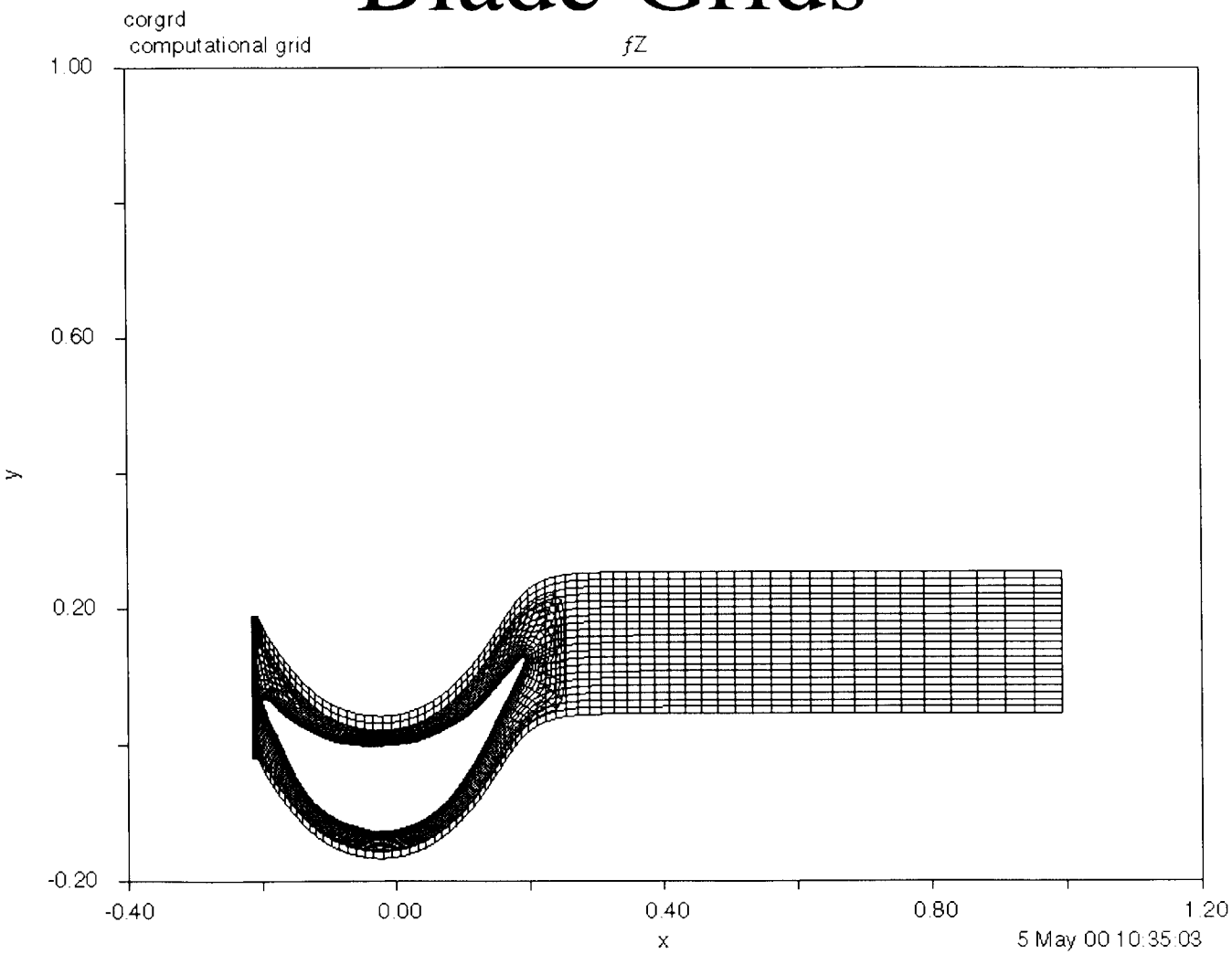
Nozzle Grids



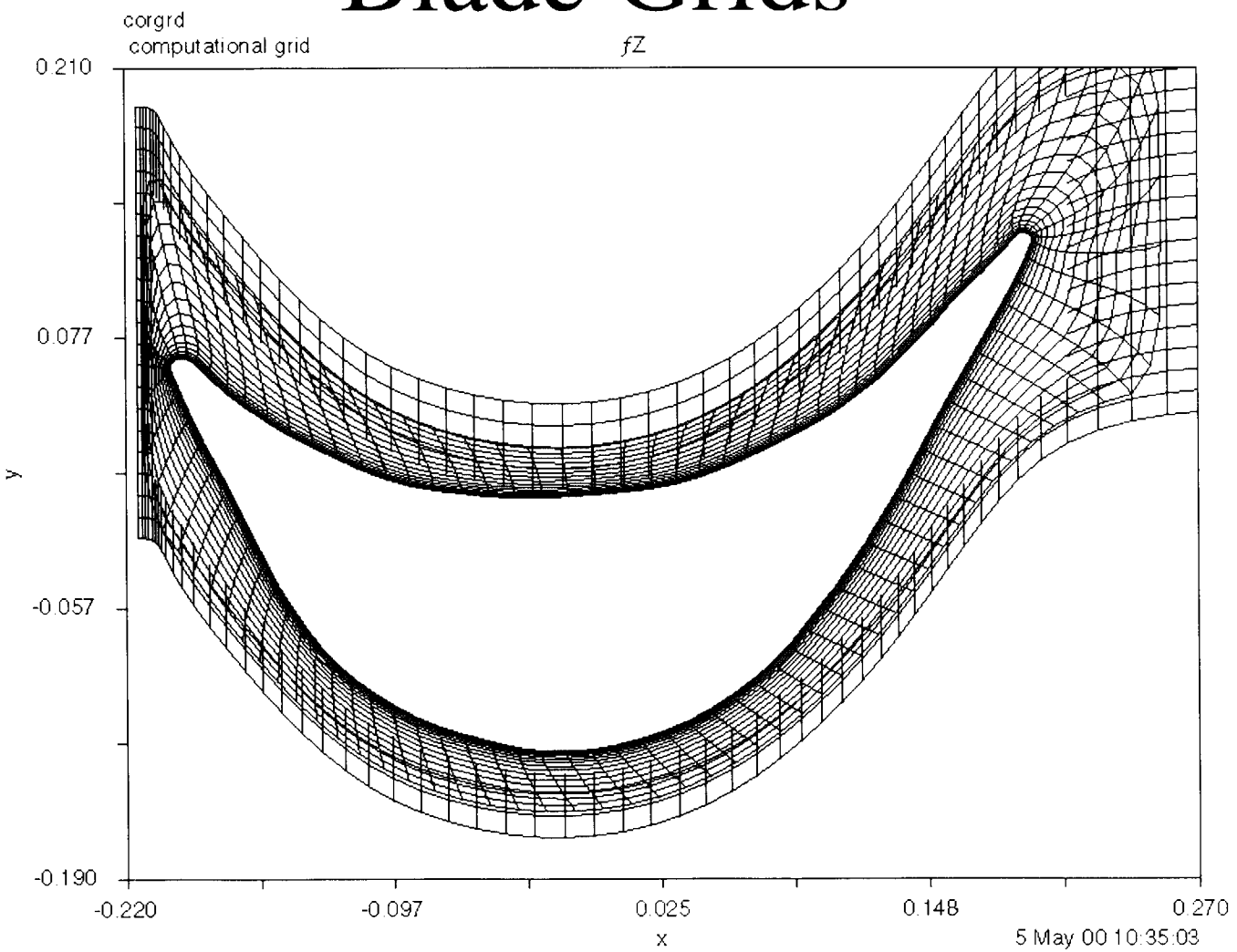
Blade Contours



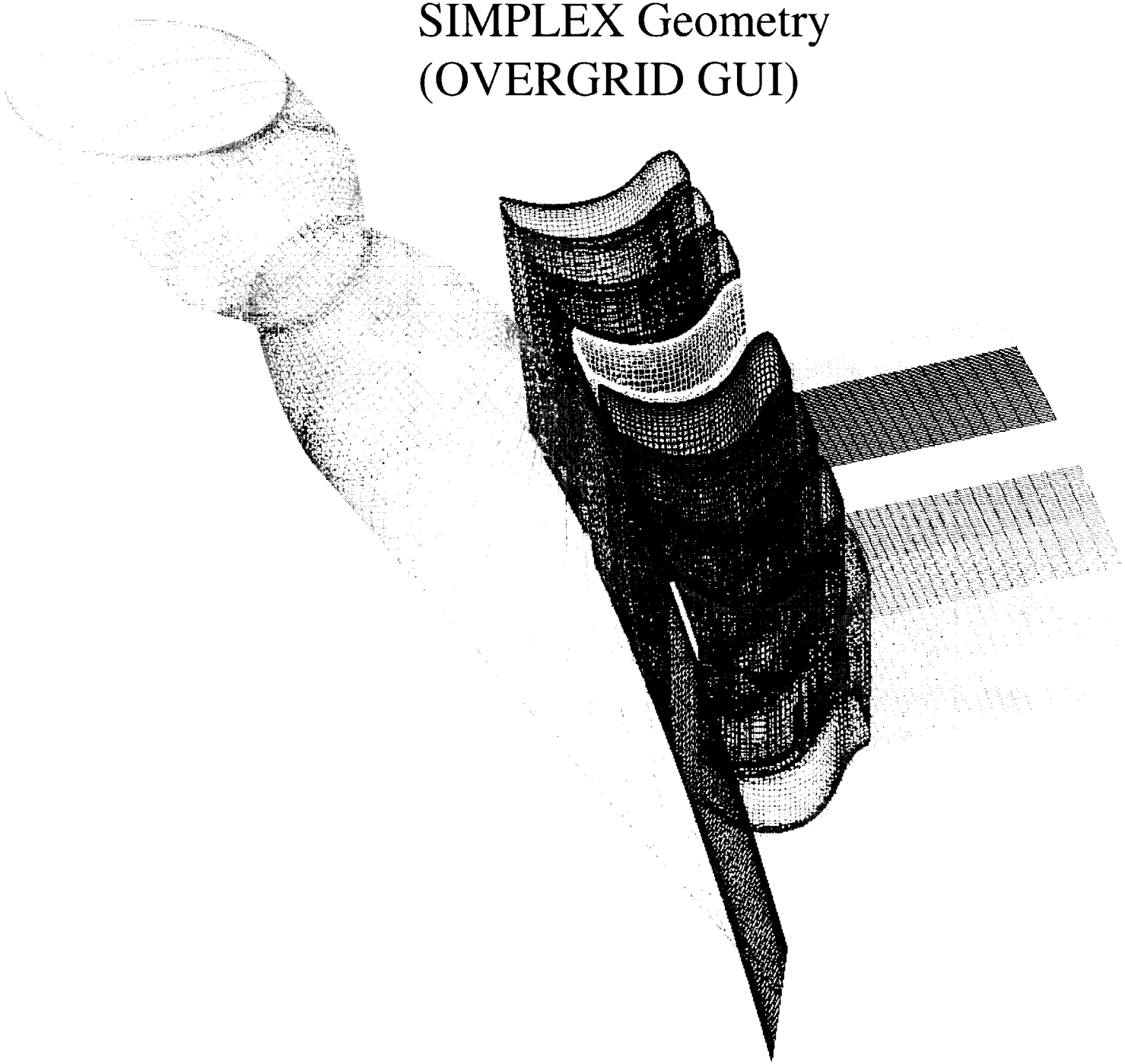
Blade Grids

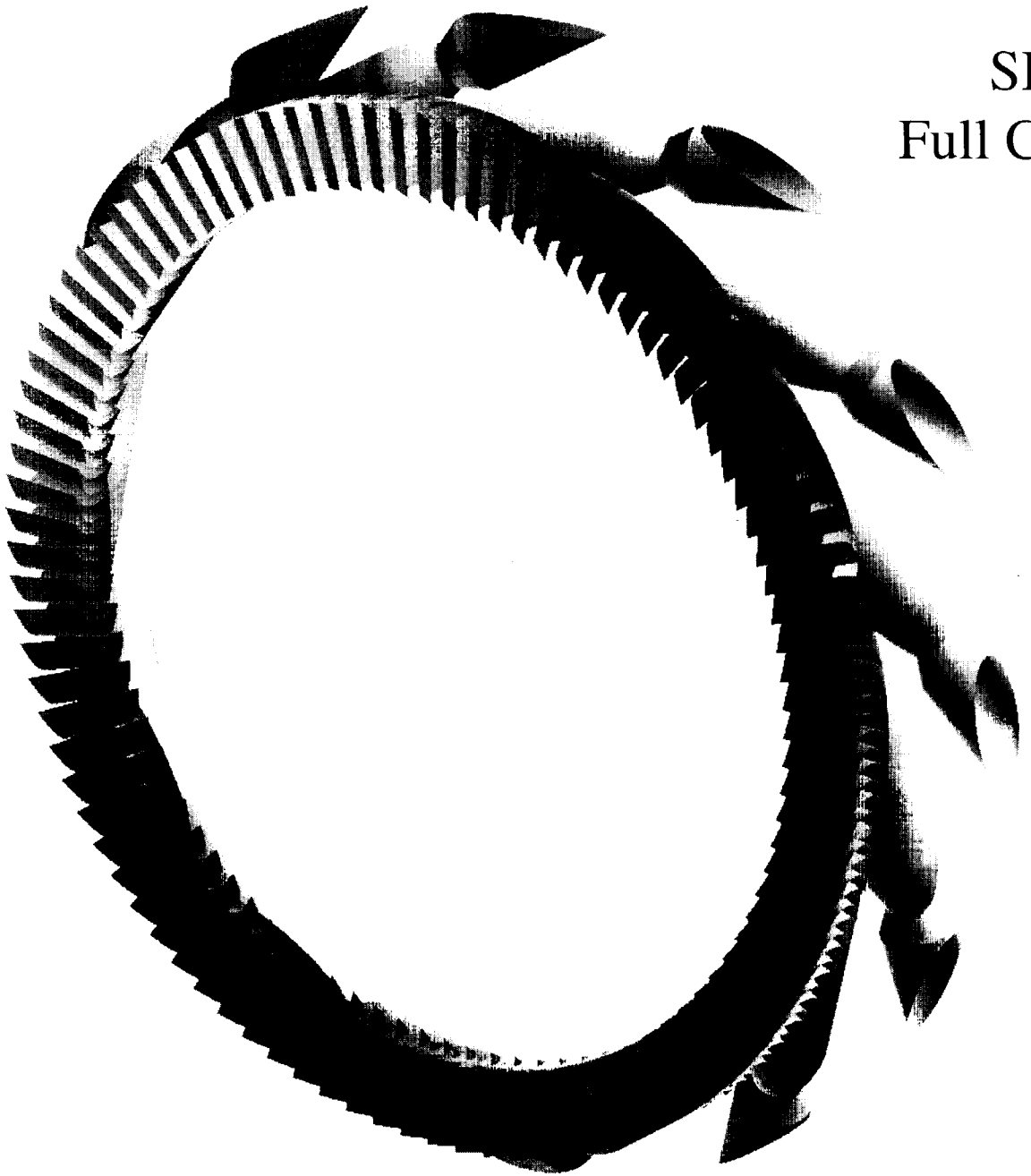

corgrd
computational grid
fZ
1.00
0.60
0.20
-0.20
y
-0.40
0.00
0.40
0.80
1.20
x
5 May 00 10:35:03

Blade Grids


corgrd
computational grid
fZ
0.210
0.077
-0.057
-0.190
y
-0.220
-0.097
0.025
0.148
0.270
x
5 May 00 10:35:03

SIMPLEX Geometry (OVERGRID GUI)





SIMPLEX
Full Configuration

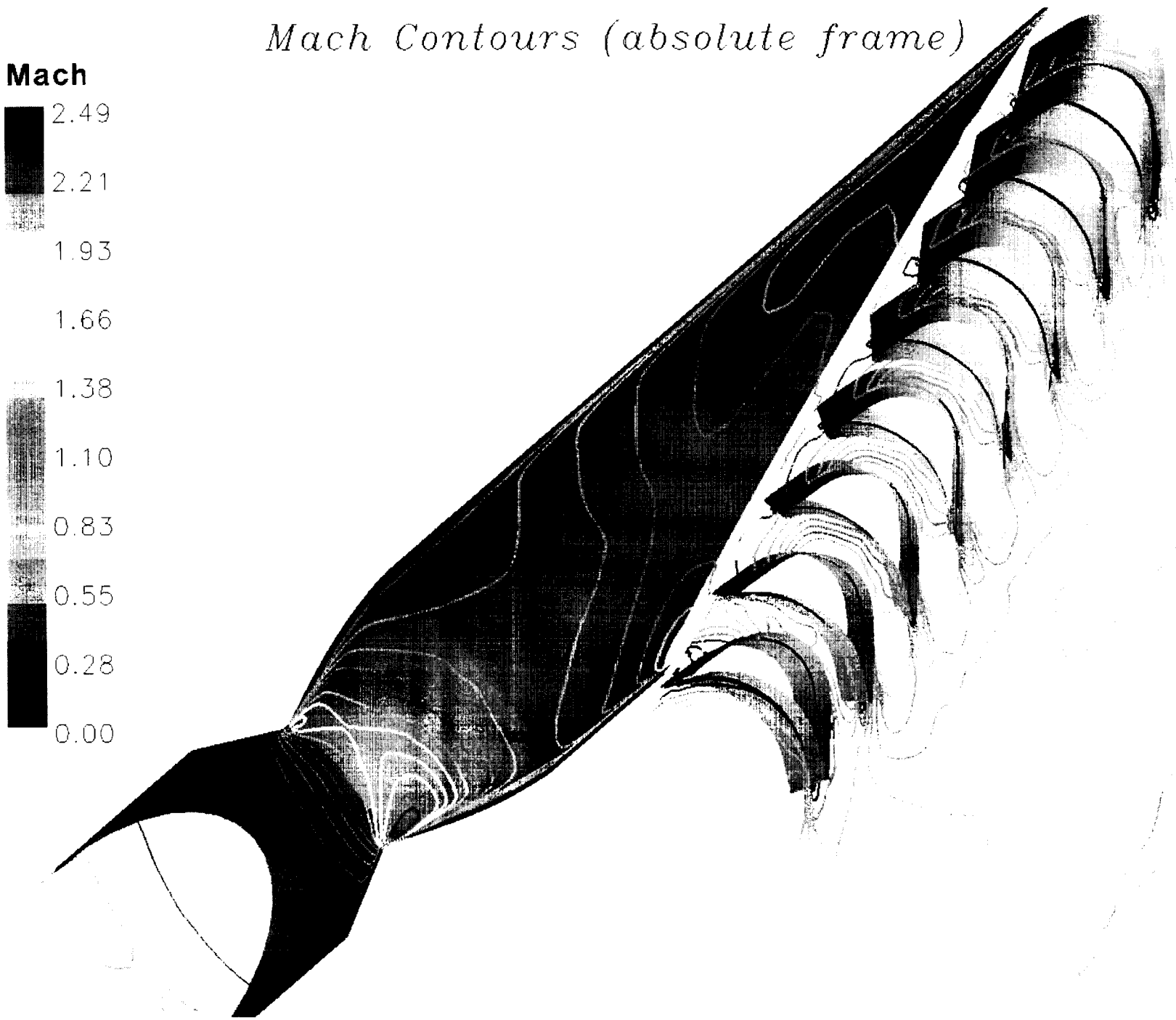
Flow Simulation

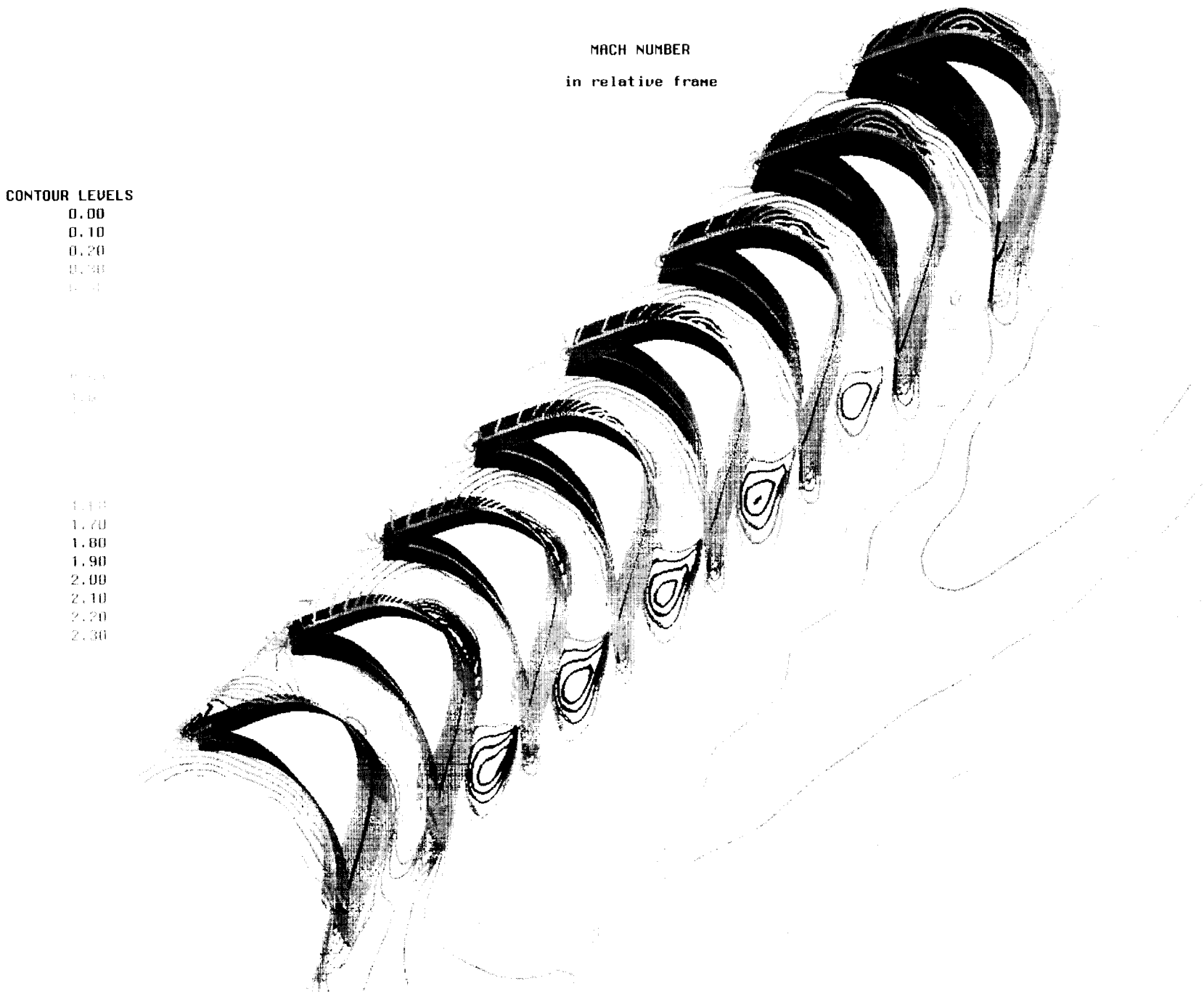
- Corsair: based on rotor3.1, solves unsteady, thin-layer Navier Stokes or Euler equations in time-accurate manner

  Code characteristics:

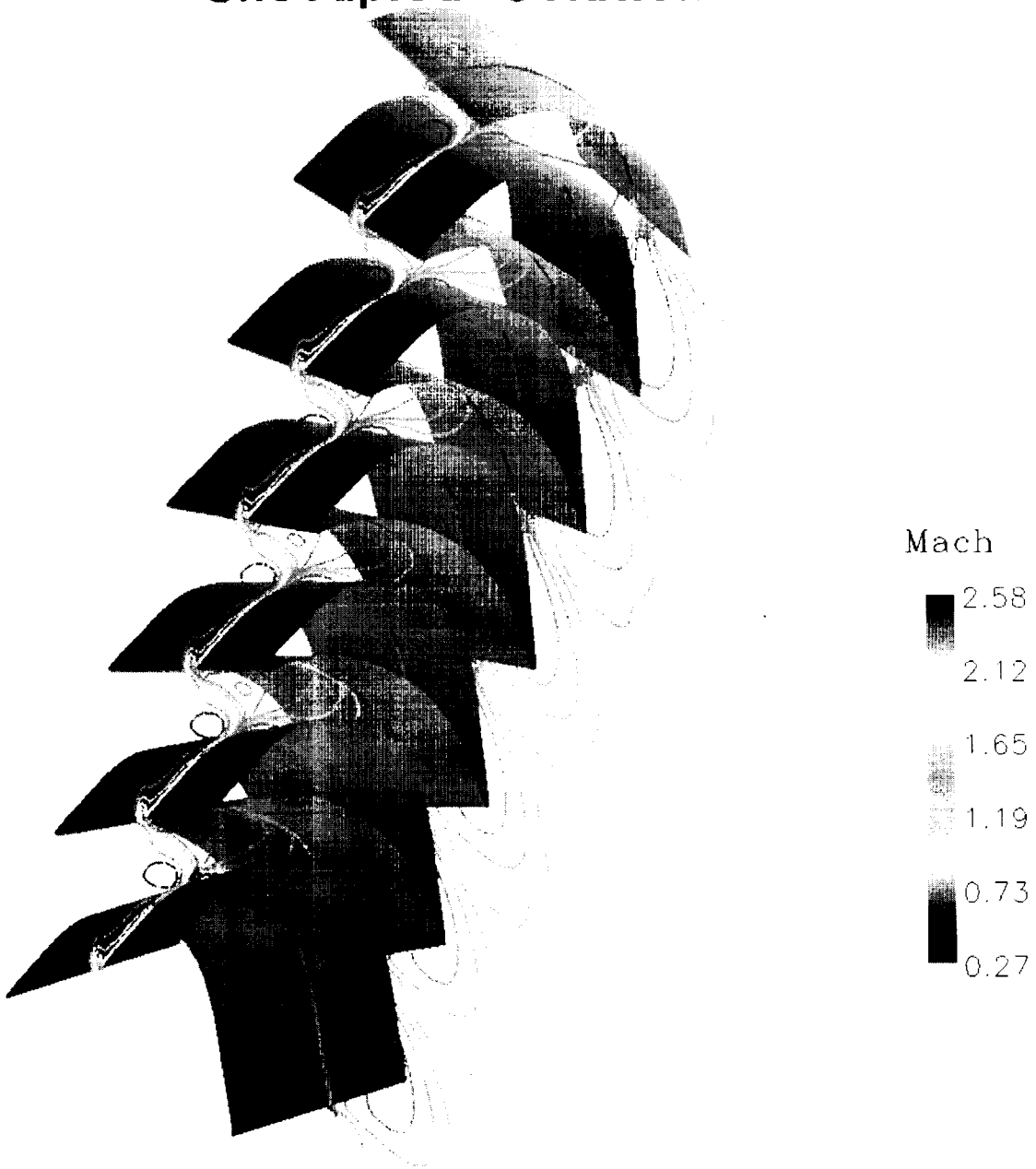
  - factored, iterative, implicit algorithm
  - Roe's upwind difference scheme
  - arbitrary blade motion/oscillation
  - slipping patch-boundary to facilitate relative motion between blades
  - multi-stage, multi-blade capability
  - etc...
- MPI: problem can be split by number of rows (3 processors) or passages (10 processors)
- 40,000 iterations per cycle


Mach
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Pressure
0.53
0.47
0.41
0.36
0.30
0.25
0.19
0.13
0.08
0.02


Mach Contours (absolute frame)
Mach
2.49
2.21
1.93
1.66
1.38
1.10
0.83
0.55
0.28
0.00

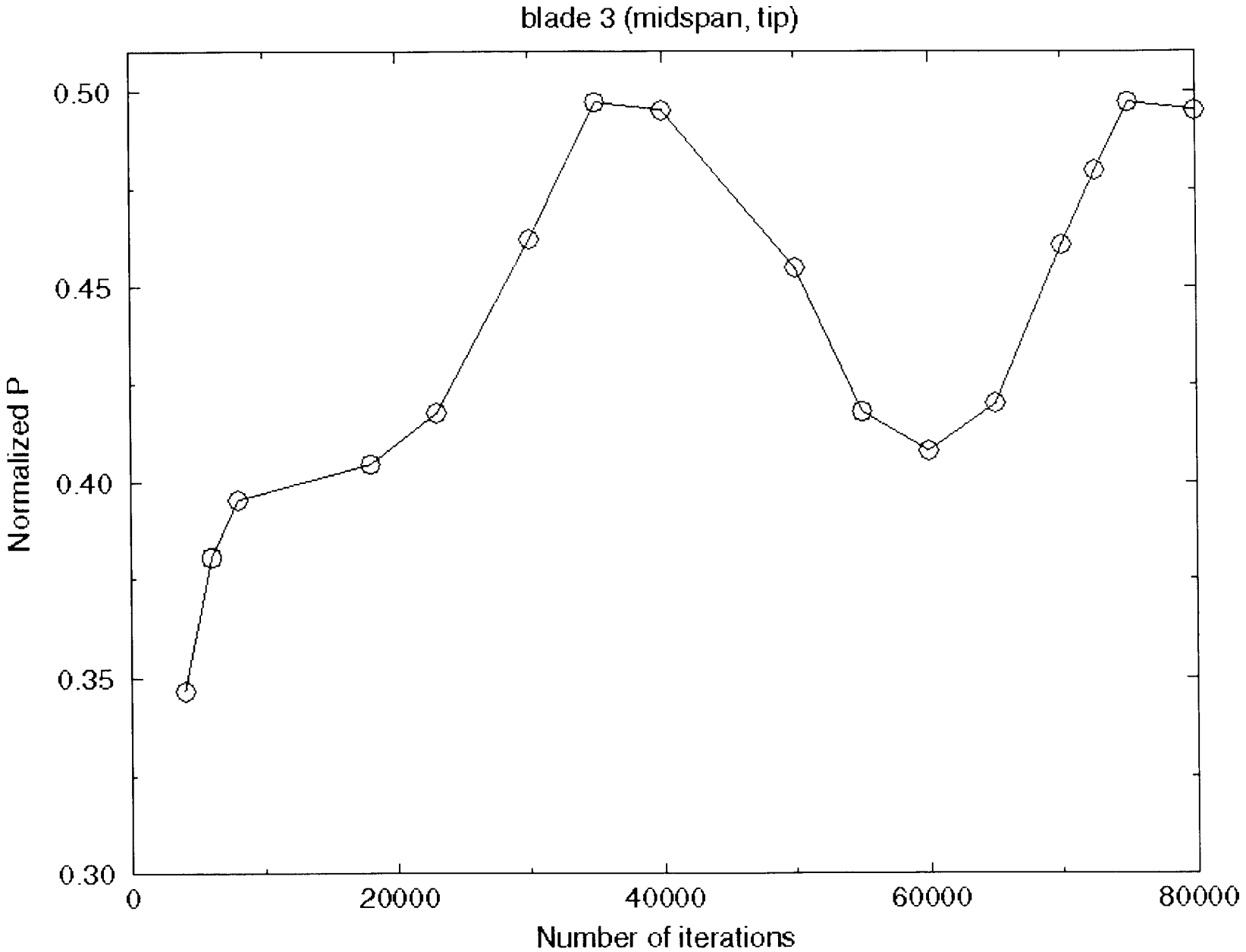

MACH NUMBER
in relative frame
CONTOUR LEVELS
0.00
0.10
0.20
1.70
1.80
1.90
2.00
2.10
2.20
2.30

Uncoupled Solution




PARTICLE TRACES COLORED BY MACH NUMBER
CONTOUR LEVELS
0.00
0.10
0.20
1.00
1.60
1.90
2.00
2.10
2.20
2.30

Periodic Check



Conclusion

- It took too long to converge 1 cycle
- Large computing resources required to implement MPI more efficiently
  - *3 processors on SGI : 1000 iterations/day*
  - *10 processors on NAS: 2500 iterations in 8 hrs (wall clock)*
- The solutions look reasonable and more realistic than the uncoupled simulation
- Consider running on PC clustered Beowulf